

# Discrete Linking Transitions for Superdeformed Bands in the A $\approx$ 80 Region

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Nuclei at the Limits  
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# Introduction

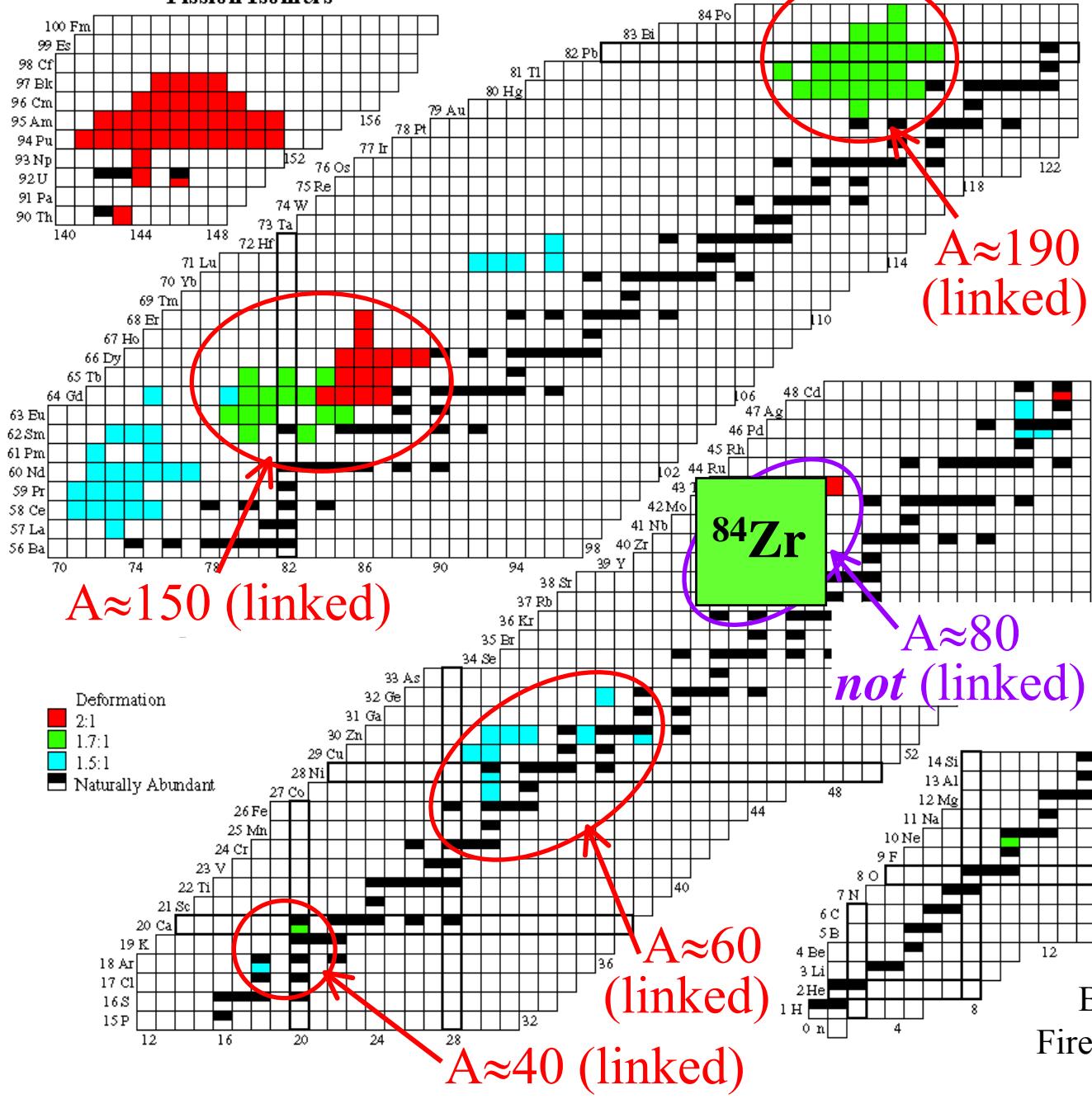
Many SD bands known; few linked to ND states.

Without links, interpretations often based solely on measured  $Q_t, J^{(2)}$  values.

With links, can compare  $E_x, I^\pi, B(\sigma\lambda)$ .

Also may provide insight on nature of decay from the SD to ND well.

## Fission Isomers



B. Singh, R. Zywina, R.B.  
Firestone, Nucl. Data Sheets 97,  
241 (2002)

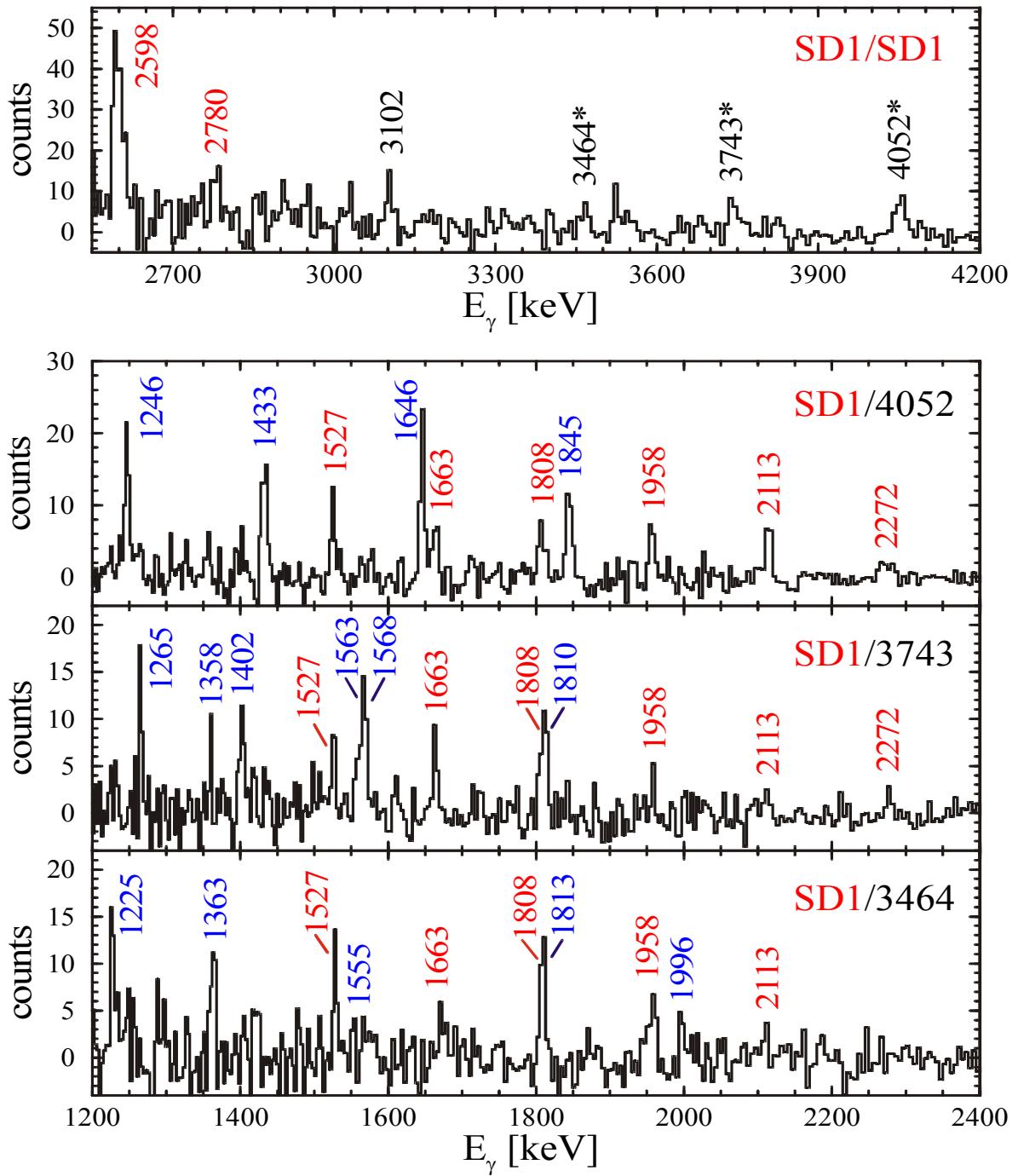
# Motivation to study $^{84}\text{Zr}$

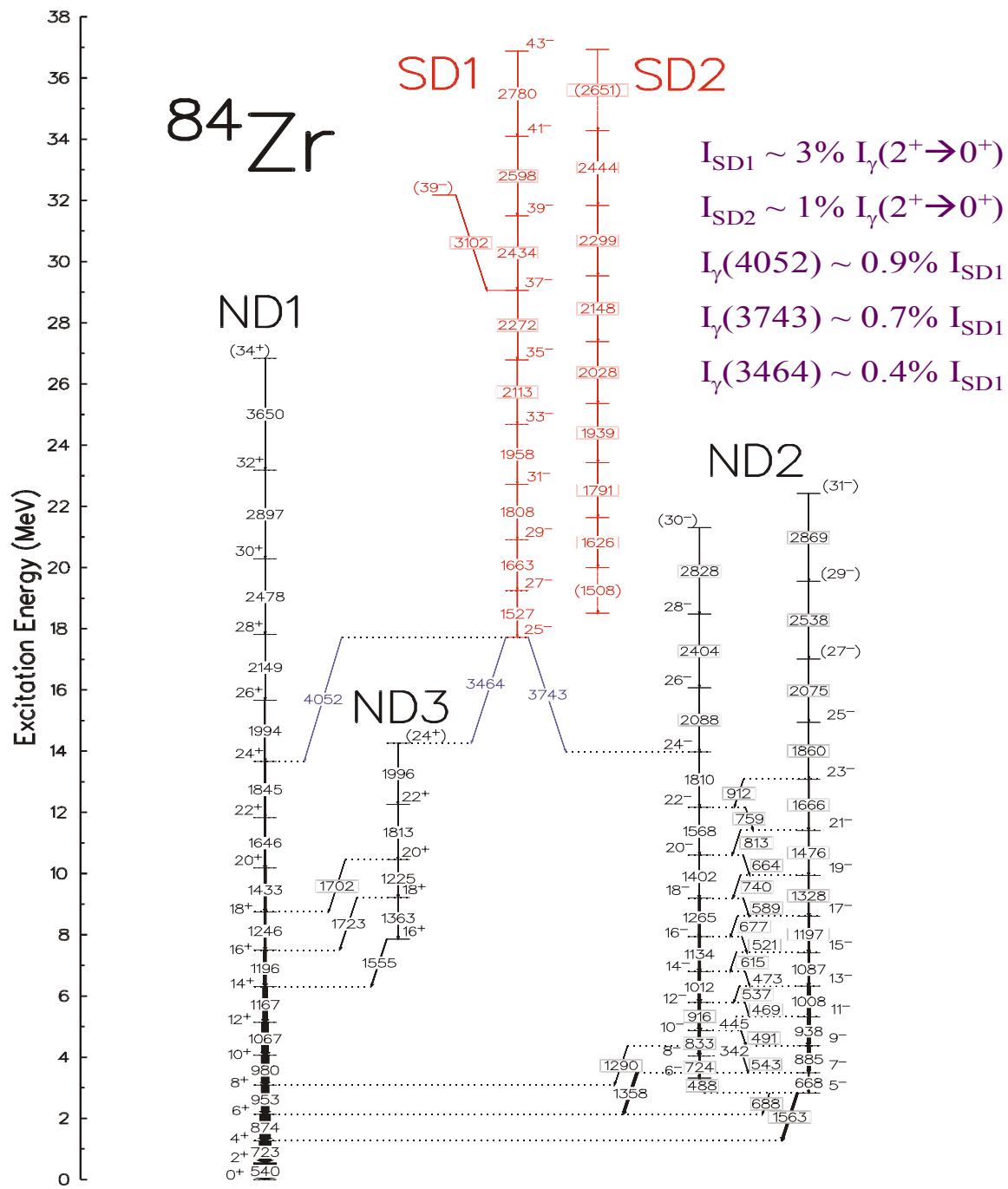
- even-even nucleus → less complicated decay scheme
- found to be “central” (i.e., doubly SD magic)  $A \approx 80$  SD nucleus [F. Lerma *et al.*, PRC **67**, 044310 (2003).]
- can be produced with significant cross section in chosen reaction....

# Experimental details

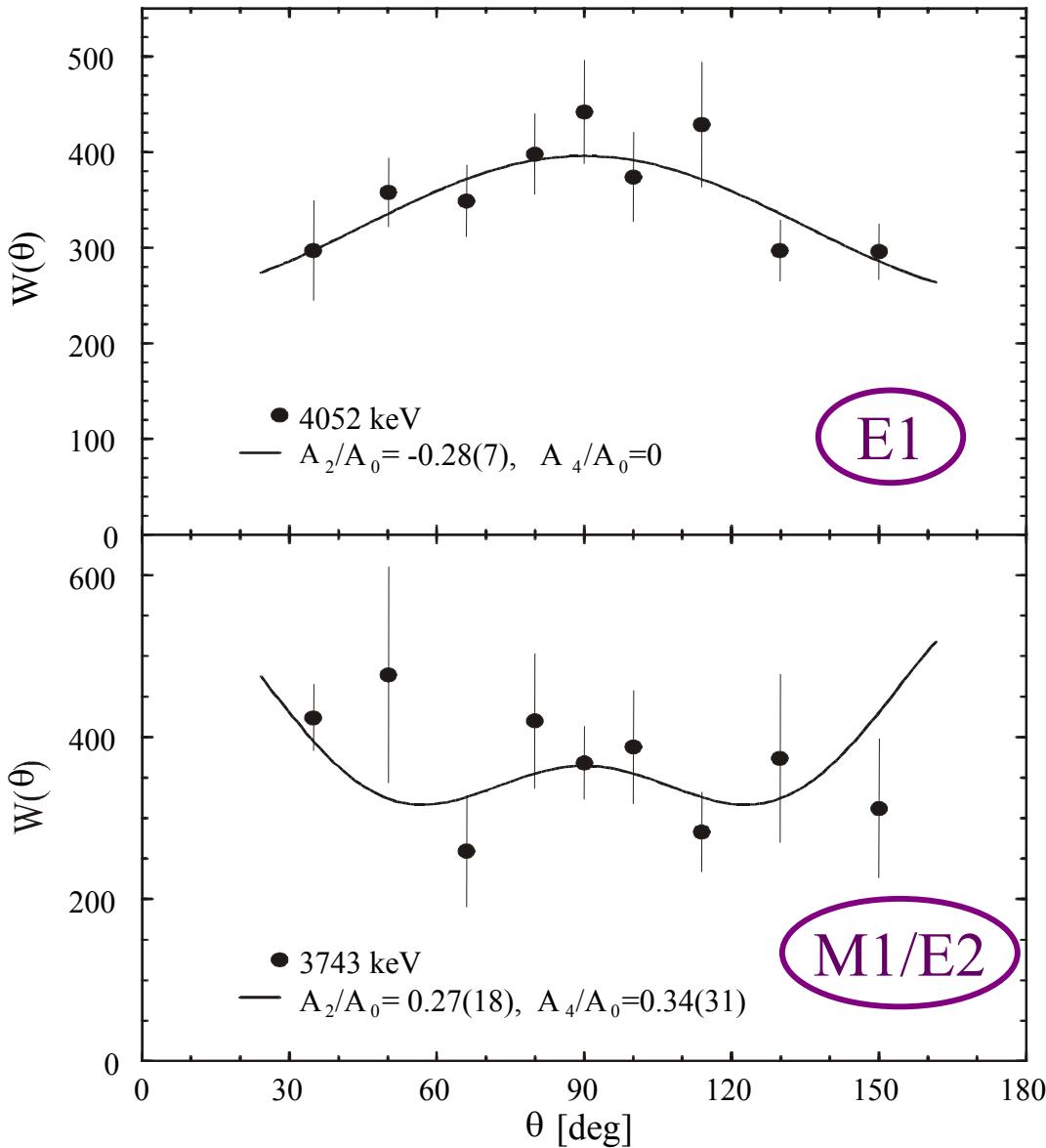
- 140-MeV  $^{32}\text{S}$  + 0.5-mg/cm<sup>2</sup>  $^{58}\text{Ni} \rightarrow ^{84}\text{Zr} + \alpha 2\text{p}$
- Gammasphere [102 Ge detectors]
- Microball [95 CsI(Tl) detectors] for charged particle detection;  $\varepsilon_{\text{p}} \approx 80\%$ ,  $\varepsilon_{\alpha} \approx 70\%$
- Total of  $2.2 \times 10^9$  events of fold 5 or higher over 6 days.

# Double-gated spectra of $^{84}\text{Zr}$ links





# Angular correlations of links



- sort  $E_\gamma(\theta)$ — $E_\gamma(all)$  matrices
- gate on *all*, project  $\theta$ -dependent spectra
- get peak areas at each  $\theta$ , norm. by  $\varepsilon(\theta, E_\gamma)$
- fit  $W(\theta) = A_0 + A_2 P_2(\cos\theta) + A_4 P_4(\cos\theta)$

$$I_0^\pi = 25^-$$

# Linking transition strengths

Use Doppler-shift attenuation method to get lifetime of SD1  $25^-$  state:

- residual centroid shifts of SD1 transitions → best-fit  $Q_t$  of band [cf.: F. Lerma *et al.*, PRC **67**, 044310 (2003)]
- similarly, centroid shift of 4052-keV link (+ effective feeding) gives  $\tau(25^-) \approx 20$  fs

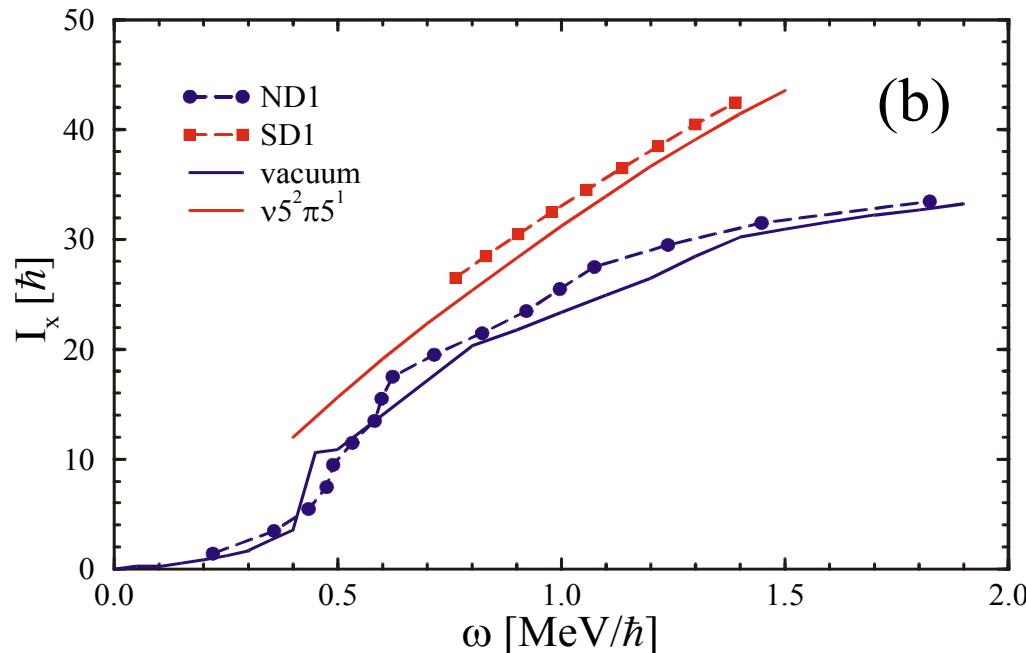
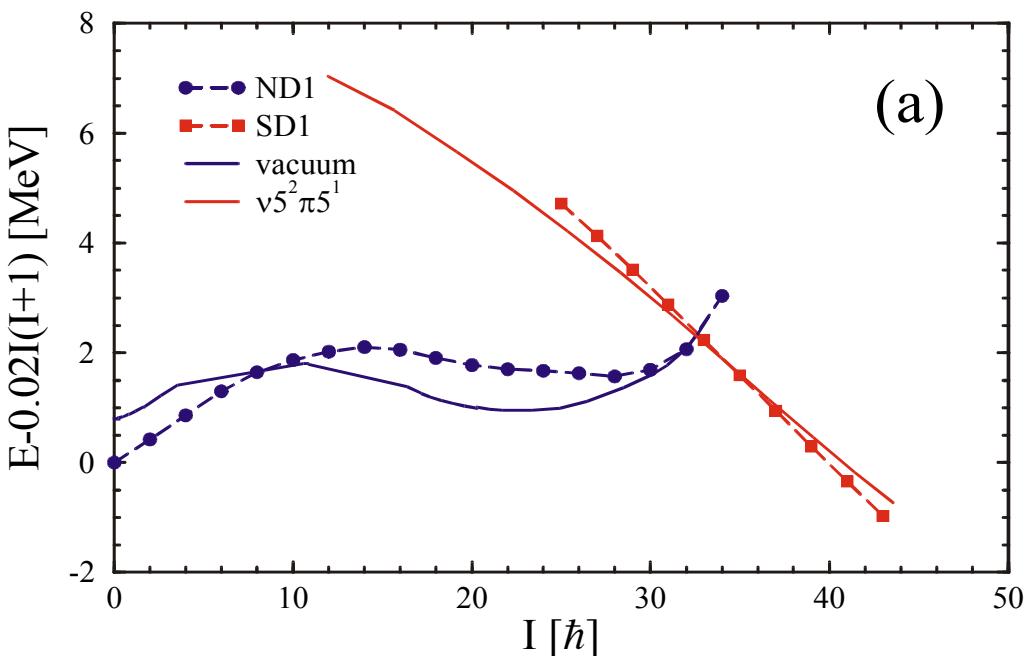
Deduce transition strengths:

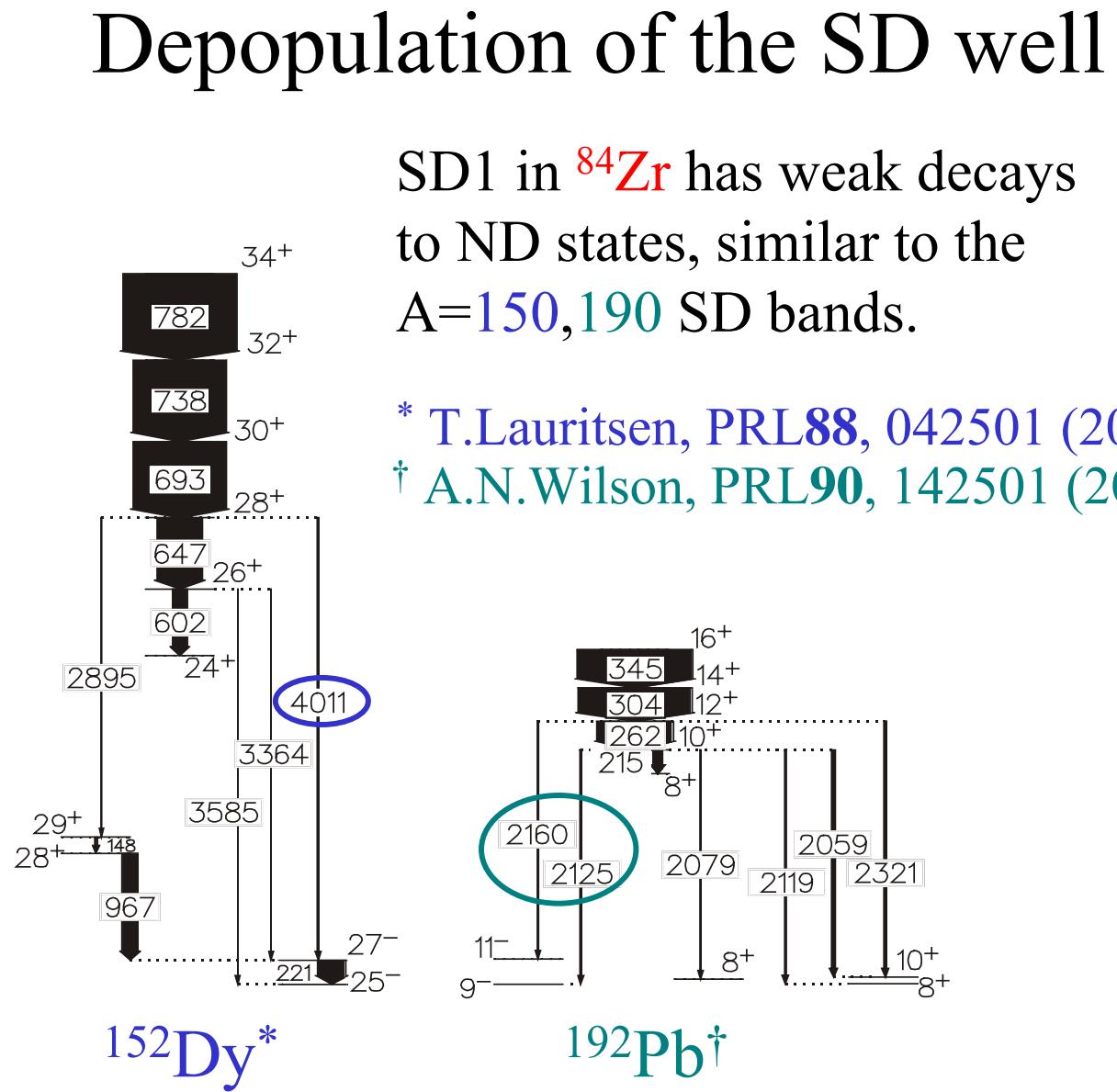
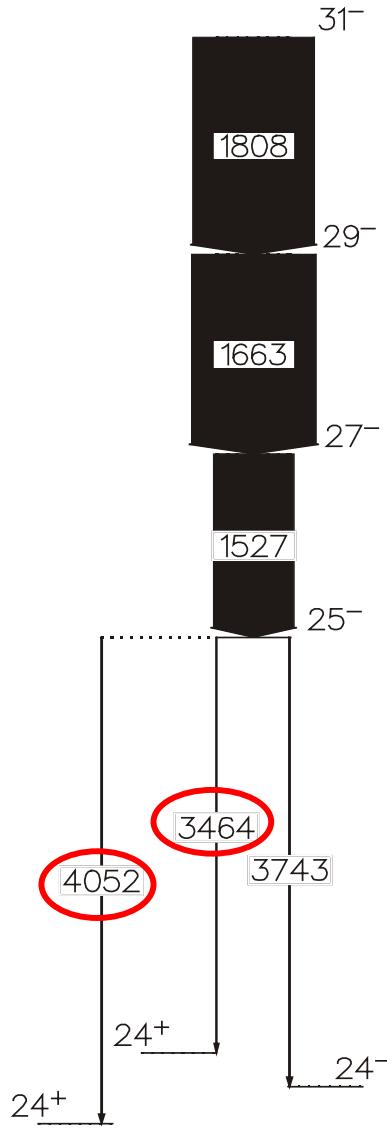
- $B(E1;4052) \sim 5 \times 10^{-6}$  W.u. [SD1 → ND1]
- $B(M1;3743) \leq 3 \times 10^{-4}$  W.u. [SD1 → ND2]
- $B(E1;3464) \sim 4 \times 10^{-6}$  W.u. [SD1 → ND3]

Compare with calculations  
using Cranked Strutinsky +  
Lipkin-Nogami pairing

$v5^2\pi5^1$  configuration  
previously assigned to SD1  
based on  $Q_t$ —now compare  
 $E_x$ ,  $I^\pi$  as well:

- ✓  $E_x$  (near ND-SD crossing)
- ✓ spin (except at alignments)
- ✓ parity

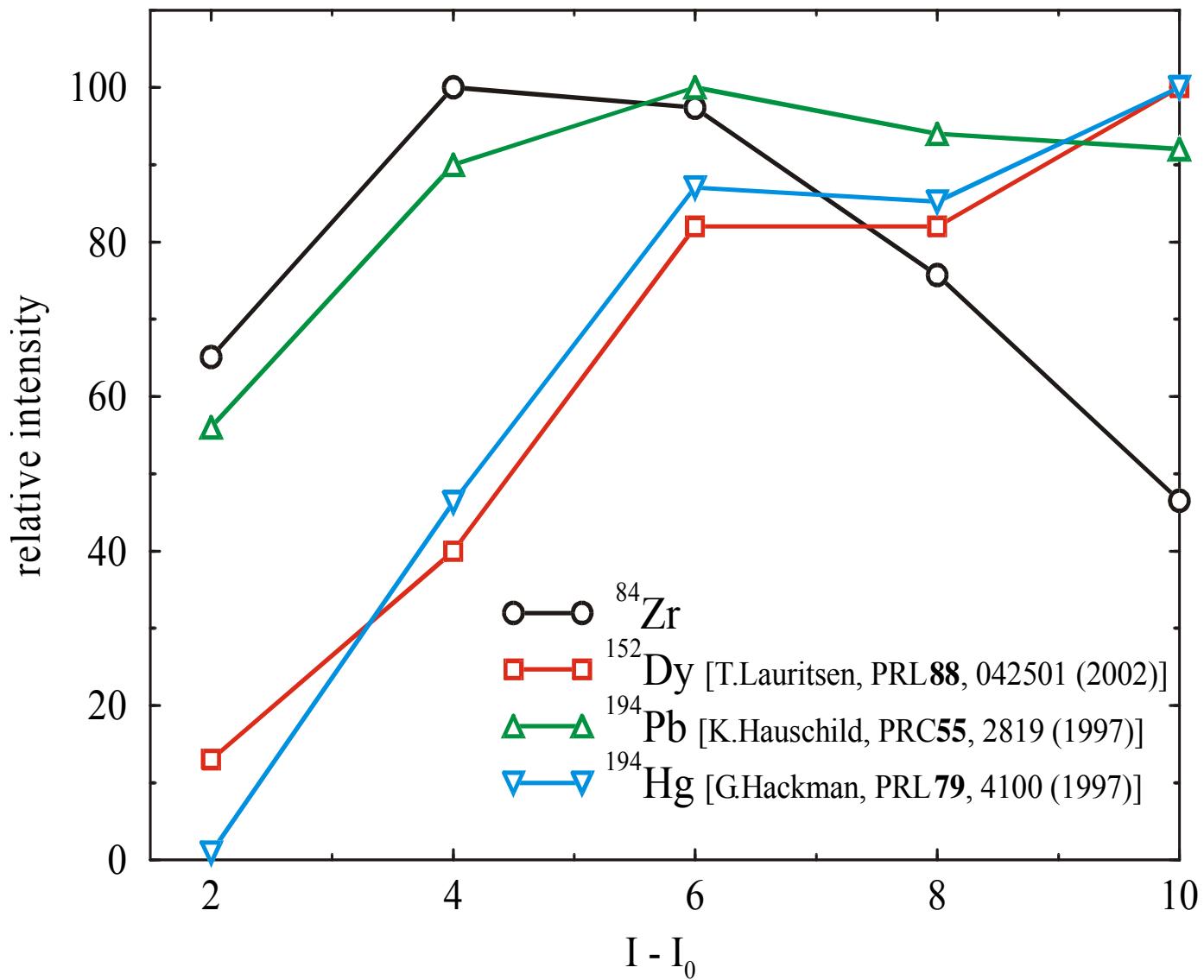




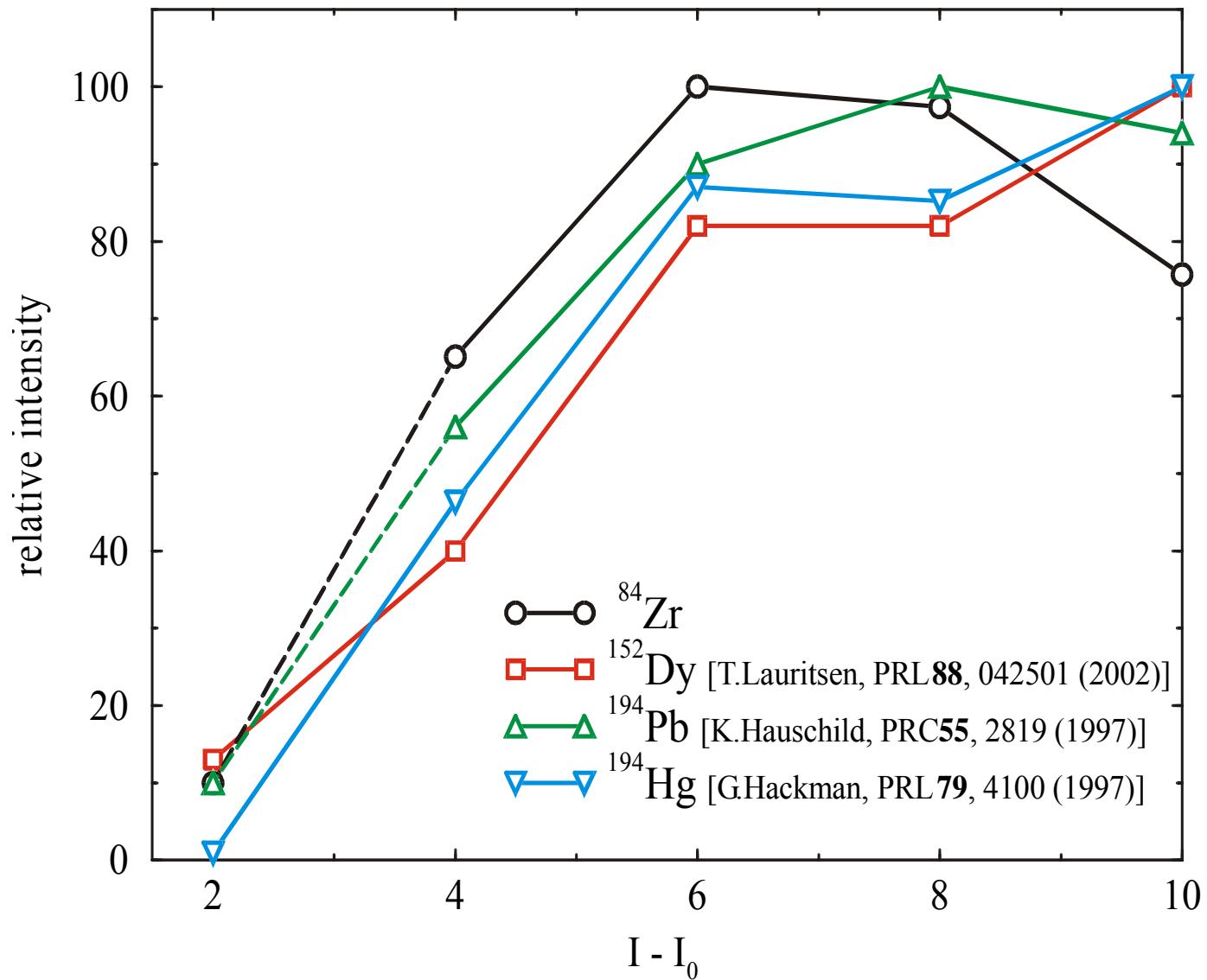
SD1 in  $^{84}\text{Zr}$  has weak decays to ND states, similar to the  $A=150,190$  SD bands.

- \* T.Lauritsen, PRL88, 042501 (2002)
- † A.N.Wilson, PRL90, 142501 (2003)

# Intensity profiles of SD bands

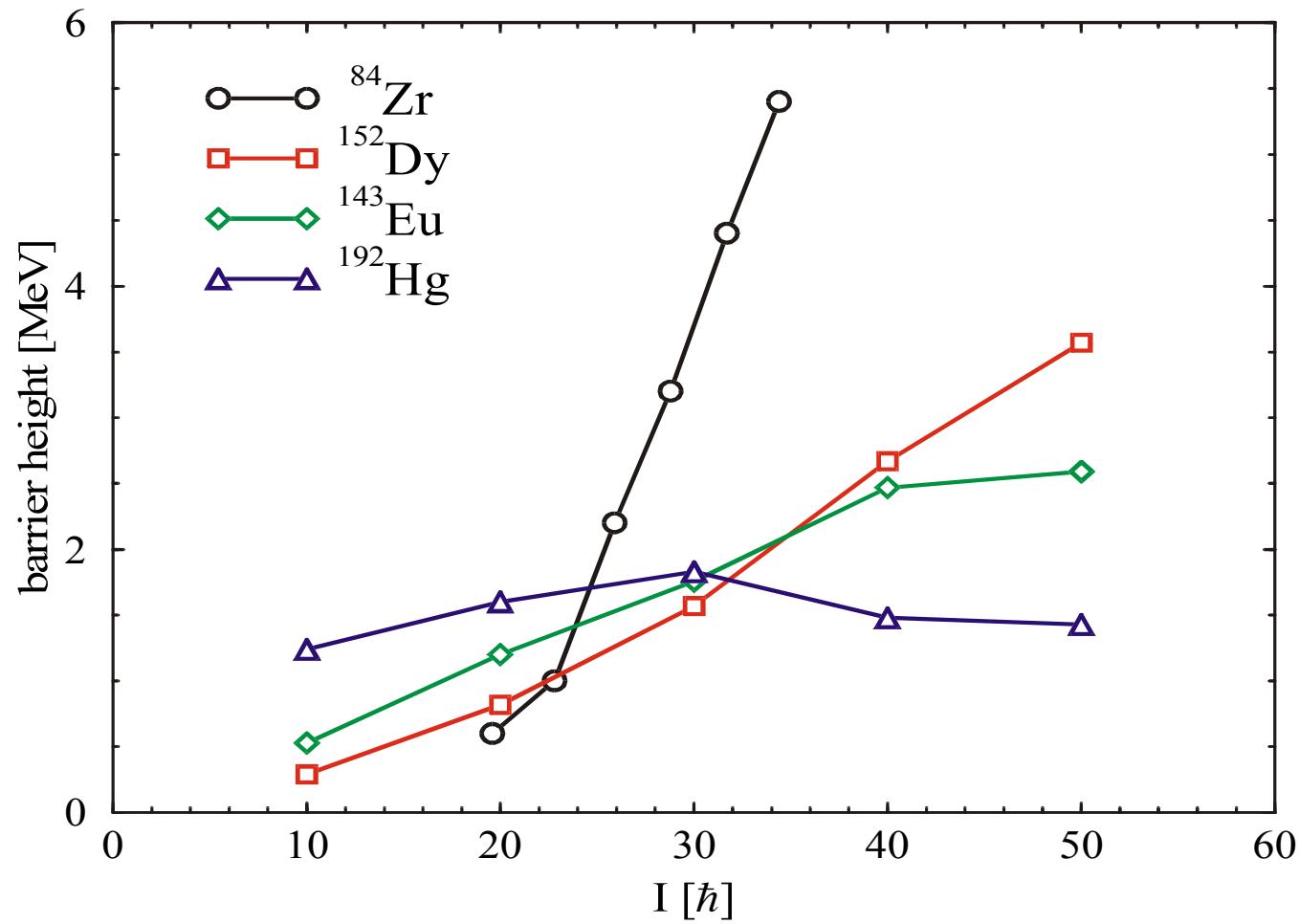


# Intensity profiles of SD bands



$^{84}\text{Zr}$  intensity falls off more rapidly.

Preliminary interpretation:  
correlated with SD-ND barrier height?



All but  $^{84}\text{Zr}$  calculated in K. Yoshida *et al.*, NPA**696**, 85 (2001) from fixed-spin potential surfaces.

$^{84}\text{Zr}$  estimated from our fixed-frequency potential surfaces (transformation is underway).

Weak decay-out explored with several statistical models, e.g.:

- E.Vigezzi *et al.*, PLB**249**,163 (1990)
- J.-z.Gu and H.A.Weidenmüller, NPA**660**, 197 (1999)
- D.M.Cardamone *et al.*, PRL**91**, 102502 (2003)

Each relates  $\Gamma_S$ ,  $\Gamma_N$ ,  $d$ ,  $F_S$  with spreading width  $\Gamma^\downarrow$ .

Get  $\Gamma^\downarrow/\Gamma_S$  limit using GW approach ( $\Gamma_S$  itself unknown for  $^{84}\text{Zr}$  SD1).

Compare ratio for  $^{84}\text{Zr}$  with results in A.N.Wilson, Fusion03 conf. proc.:

nuclide	$I^\pi$	$\Gamma^\downarrow/\Gamma_S$	B(E1) [W.u.]
$^{192}\text{Pb}$	$10^+$	$1.1 \times 10^7$	$5 \times 10^{-7}$
	$12^+$	$9.8 \times 10^4$	$2 \times 10^{-7}$
$^{194}\text{Pb}$	$8^+$	$2.0 \times 10^4$	$2 \times 10^{-8}$
	$10^+$	$3.3 \times 10^3$	$5 \times 10^{-8}$
$^{194}\text{Hg}$	$12^+$	$2.6 \times 10^2$	$7 \times 10^{-9}$
$^{152}\text{Dy}$	$28^+$	$6.0 \times 10^2$	$2 \times 10^{-6}$
$^{84}\text{Zr}$	$25^-$	$> 4.4 \times 10^6$	$5 \times 10^{-6}$

# Summary

- “Full” characterization of a  $A \approx 80$  SD band
  - $^{84}\text{Zr}$  SD1 first to be linked to ND states  $\rightarrow E_x$  (several neighbors studied too—no luck!)
  - Angular correlations  $\rightarrow I^\pi$
  - DSAM  $\rightarrow$  lifetimes/ $Q_t$   $\rightarrow B(\sigma\lambda)$
- Results are consistent with CS-LN calculations for  $\nu 5^2\pi 5^1$  configuration [esp.  $E_x(I)$  in crossing region]
- $^{84}\text{Zr} \sim ^{152}\text{Dy}$  [spin, energy,  $B(E1)$ ] and  $^{192}\text{Pb}$  [ $\Gamma^\downarrow/\Gamma_S$ ].
- “Unique” intensity profile *may* reflect more rapid change in barrier height (calculations in progress...).

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Parting thought...



“You are the weakest link—goodbye!”